BASIC ENGINE THEORY from Gasoline FAQ's 1 to 4

10.2 From Honda Civic to Formula 1 winner.

[The following is edited from a post in a debate over the advantages of water injection. I tried to demonstrate what modifications would be required to convert my own 1500cc Honda Civic into something worthwhile :-).]

There are many variables that will determine the power output of an engine. High on the list will be the ability of the fuel to burn evenly without knock. No matter how clever the engine, the engine power output limit is determined by the fuel it is designed to use, not the amount of oxygen stuffed into the cylinder and compressed. Modern engines designs and gasolines are intended to reduce the emission of undesirable exhaust pollutants, consequently engine performance is mainly constrained by the fuel available.

My Honda Civic uses 91 RON fuel, but the Honda Formula 1 turbo charged 1.5 liter engine was only permitted to operate on 102 Research Octane fuel, and had limits placed on the amount of fuel it could use during a race, the maximum boost of the turbo chargers was specified, as was an additional 40kg penalty weight. Standard 102 RON gasoline would be about 96 (R+M)/2 if sold as a pump gasoline. The normally-aspirated 3.0 liter engines could use unlimited amounts of 102RON fuel. The F1 race duration is 305 km or 2 hours, and it's perhaps worth remembering that Indy cars then ran at 7.3 psi boost.

Engine	Standard	Formula One	Formula One
Year	1986	1987	1989
Size	1.5 liter	1.5 liter	1.5 liter
Cylinders	4	6	6
Aspiration	normal	turbo	turbo
Maximum Boost		58 psi	36.3 psi
Maximum Fuel		200 liters	150 liters
Fuel	91 RON	102 RON	102 RON
Horsepower @ rpm	92 @ 6000	994 @ 12000	610 @ 12500
Torque (lb-ft @ rpm)	89 @ 4500	490 @ 9750	280 @ 10000

The details of the transition from Standard to Formula 1, without considering engine materials, are:

1. Replace the exhaust system. HP and torque both climb to 100.

2. Double the rpm while improving breathing, you now have 200hp but still only about 100lb-ft of torque.

3. Boost it to 58psi - which equals four such engines, so you have 1000hp and 500lb-ft of torque.

Simple?, not with 102 RON fuel, the engine/fuel combination would knock the engine into pieces, so....

4. Lower the compression ratio to 7.4:1, and the higher rpm is a big advantage - there is much less time for the end gases to ignite and cause detonation.

5. Optimize engine design. 80 degree bank angles V for aerodynamic reasons, and go to six cylinders = V6

6. Cool the air. The compression of 70F air at 14.7psi to 72.7psi raises its temperature to 377F. The turbos churn the air, and although they are about 75% efficient, the air is now at 479F.

7. The huge intercoolers could reduce the air to 97F, but that was too low to properly vaporize the fuel.

8. Bypass the intercoolers to maintain 104F.

9. Change the air-fuel ratio to 23% richer than stoichiometric to reduce combustion temperature.

10. Change to 84:16 toluene/heptane fuel - which complies with the 102 RON requirement, but is harder to vaporize.

11. Add sophisticated electronic timing and engine management controls to ensure reliable combustion with no detonation.

You now have a six-cylinder, 1.5 liter, 1000hp Honda Civic.

For subsequent years the restrictions were even more severe, 150 liters and 36.3 maximum boost, in a still vain attempt to give the 3 liter, normally-aspirated engines a chance. Obviously Honda took advantage of the reduced boost by increasing CR to 9.4:1, and only going to 15% rich air-fuel ratio. They then developed an economy mode that involved heating the liquid fuel to 180F to improve vaporization, and increased the air temp to 158F, and leaned out the air-fuel ratio to just 2% rich. The engine output dropped to 610hp @ 12,500 (from 685hp @ 12,500 and about 312 lbs-ft of torque @ 10,000 rpm), but 32% of the energy in the fuel was converted to mechanical work. The engine still had crisp throttle response, and still beat the normally aspirated engines that did not have the fuel limitation. So turbos were banned. No other F1 racing engine has ever come close to converting 32% of the fuel energy into work [136].

In 1995 the FIA listed a detailed series of acceptable ranges for typical components in racing fuels for events such as F1 races, along with the introduction of detailed chromatographic "fingerprinting" of the hydrocarbon profile of the fuel [137]. This was necessary to prevent novel formulations of fuels, such as produced by Honda for their turbos.